Journal of Educational Research and Reviews
Vol. 12(5), pp. 87-97, May 2024
doi:10.33495/jerr_v12i5.24.104
ISSN: 2384-7301
Research Paper

Professional Development of In-Service Teachers in Stem Education

Michal Nachshon[1]* • Amira Rom[2]

[1]Development and Research in STEM Education, Oranim, College of Education, Israel.
[2]Education & Psychology department, the Open University of Israel.

*Corresponding author. E-mail: michal_na@oranim.ac.il. Tel. 972-506282451.

Accepted 20th May, 2024.

Abstract. Professional development of in-service teachers within the context of STEM (Science, Technology, Engineering, and Mathematics) education, explored interdisciplinary principles and the integration of advanced technology, particularly 3D printers, into STEM teaching. Emphasizing the necessity of nurturing integrative thinking in educators also arises the importance of STEM education in addressing complex global challenges and fostering essential skills like critical thinking, creativity, and collaboration among students. The aim of this study was to identify how are interdisciplinary principles of STEM education expressed in a study unit developed by elementary school teachers and how graduate students who study towards a degree in science education perceive the integration of a 3D printer in STEM education. Through a qualitative research paradigm, the study analyzes data collected from 30 elementary school teachers, who participated in a two-year educational program, focused on developing interdisciplinary study units. Findings revealed teachers' positive attitudes towards interdisciplinary learning, with challenges primarily centered on classroom management and pedagogical integration. Additionally, the integration of 3D printers and art into STEM education (STEAM) was investigated among 28 graduate students training to be elementary school teachers, highlighting benefits of experiential learning with advanced technology in enhancing students' abilities and skills. The study concludes by advocating for the widespread inclusion of 3D printers in high school curricula to provide students with practical experiences and foster innovation. It recommends further research to explore high school teachers' perspectives on STEM education, thereby enriching understanding and facilitating the effective implementation of STEM approaches across educational levels.

Keywords: Elementary school teachers, STEM education, 3D printer.

INTRODUCTION

Teachers go through stages in their professional career during which they experience changes in the requirements, in their sense of professional ability, and their attitudes toward their profession and toward the organization where they work. The social, psychological, economic, cultural, and legal processes occurring in the work environment also change over time. All these affect teachers' professional development and their place in the school where they work and their functioning in it.

Processes occurring nowadays, among which are the globalization of knowledge and accelerated development of technology, intensify uncertainty and set before us the task of coping with complex challenges and problem-solving. The key to resolving these situations cannot be based on a causal, simple, and unambiguous explanation. Rather, the answer must be found in a blend of knowledge and understanding of disciplines as well as integration between them.

The solution to the world's central problems, such as climate change, poverty explosion, human rights, energy resources etc., will not be found in a single field but in a better understanding of the relations among different fields of knowledge. The changes in the global labor market also require people who better understand the relations among different knowledge domains, who can cope with new problems, implement the thinking of experts in a flexible manner and effectively communicate with other people with different perspectives vis-à-vis the same issue.

For these reasons, arises the need to nurture integrative thinking. Multidisciplinary learning, inter-disciplinary learning, and meta-disciplinary learning are three integrated learning approaches that have been examined according to some aspects, among which are identification of the basis for integration, defining learning goals, and assessing the level of integration when planning assignments (Helmane and Briska, 2017). The goal of integrative learning is to support the student's individual development. Integrative learning promotes students' acquisition of knowledge and skills, as well as their intellectual, emotional, and social development. Through integrative learning, the learning is done by being connected to the learner's life. Of the three learning approaches to integrative learning, multidisciplinary learning approach is tied to learning a certain subject or theme from the perspective of different knowledge areas. In meta-disciplinary learning, the research processes, and topics lead to innovative and unexpected solutions, and in interdisciplinary learning, the students learn generic skills that cross knowledge areas with the aim of explaining a phenomenon or solving a problem.

The level of integration in multidisciplinary learning is assessed by concepts and ideas that students are expected to handle. In meta-disciplinary learning, it is examined by looking at the type of questions and issues with which the students are involved that are related to real life and the way in which they reach answers. In interdisciplinary learning, the level of integration is measured by identifying thinking strategies that students are expected to use in completing their assignments and checking whether they have been adopted.

Interdisciplinary learning is appropriate for STEM learning. STEM learning is a process through which students integrate and blend knowledge, tools and skills, theories, concepts, data, perspectives, and practices from two or more disciplines. The goal of STEM learning is to produce outcomes, to explain phenomena, to solve problems in ways that were not possible using a single discipline. The educational way of thinking at the basis of STEM learning integration comprises an integral part of the forward thinking and development of the Western world. It serves as a springboard for the growth and socio-economic leadership of each citizen, for building students' readiness for a changing world through equity, for nurturing creativity and excellence, and for developing the future generation. This approach is compatible with all students from a variety of education levels (Pramesti *et al*., 2022) and allows educators to teach while integrating problem-emerging skills to equip the students (Xue, 2022). Many studies have shown that a learning process in STEM can improve cognitive skills (Weyer and Dell'Erba, 2022). Samara and Kotsis (2023) reported about teachers' perceptions of applying this approach in schools. They noted that it promotes interest in learning fosters motivation and 21st century skills such as problem-solving and order teamwork, critical thinking, creative thinking, and students' inquiry skills. Also, Quigley *et al*. (2019) found in their analysis significant overlap in ideas of connected learning and STEAM, notably a shared emphasis on design, collaboration, and contextualized learning.

There are five guiding principles for effective STEM instruction: (1) focus on integration, (2) establish relevance, (3) emphasize twenty-first-century learning skills, (4) challenge the students, and (5) mix it up by providing a variety of instructional tasks and ways for your students to demonstrate their understanding (Vasquez *et al*., 2013). STEM, according to this approach, is not a curricular component, but a tool for understanding and implementing instructions, applying knowledge, working as a team, listening to, and offering criticism to one's peers and understanding the relevance of the acquired knowledge. Not every learning experience includes these components, but it is important that teachers have a deep understanding of the connections that can be made between their students in order to be able to help them to establish a community of active learners focusing on doing hands-on projects. Pramesti *et al*. (2022) also noted the main teaching goals of the STEM approach focusing on preparing students for problem solving in an innovative and creative way, integrating critical thinking – cooperatively – through interpersonal communication with the goal of promoting acquisition of new information and knowledge enhancement.

The integration of STEM subjects in a curriculum is done in several different ways. Teachers engage students using stimuli while fostering critical questioning skills. They enable students to find ways to solve problems by identifying the interconnected scientific knowledge areas where answers may be found. Moreover, the integration of scientific experience and collaborative processes in class, as well as the integration of advanced technologies (e.g., 3D printer), intensify the motivation and impart significance to the subjects being taught (Reinking and Martin, 2019). Introducing advanced applied scientific experiments constitutes a significant part of STEM education. It promotes digital literacy together with creative thinking during the process of grappling with an open assignment that includes a number of answers and fosters thinking processes and independent learning, done at students' personal pace who continually learn from their mistakes and correct them until reaching their goals.

The knowledge and skills acquired while learning the knowledge areas of STEM education accelerate cognitive development and are based on acquaintance with interdisciplinary phenomena and ideas, on the natural connectedness of the four knowledge areas and experience in planning solutions to complex, interrelated problems, using up-to-date technology and tools and suiting them to the modern workforce. The basis for

Table 1. The three-year continuing education program.

Stage and duration	Content
Stage 1 – 30 hours	The essence of the integrative approach for STEM subjects, the constructionist approach, thinking skills, integrating mathematics and science (using soap bubbles) in STEM activities in Israel and abroad.
Stage 2 – 70 hours	Space – As an example of learning using the integrative approach, SEL, dialogue in collaborative work, experiencing integrative projects, 21st century skills, anchoring for engineering thinking using the engineering design process; evaluation: the teacher's work and the students' activities. Teachers work in groups and are guided by mentors.
Stage 3 – 30 hours	Integrating advanced technology and art through experiencing developing a product using a 3D printer, the expression of biomimetics[1] in learning outside of the classroom through a field trip to a botanical garden.

learning is a passion for knowledge, and curiosity and respect for science and engineering, through the creation of a collaborative process led by educators, in formal and informal frameworks. So STEM education equips students with the necessary capabilities required for future changes. One way to do this is through the engineering design process, activities that reflect problems in the real world and their link to conceptual learning (King and English, 2016).

There are those who prefer to also integrate art among the STEM fields - STEAM (science, technology, engineering, arts, and mathematics). In a study by Pramesti *et al.* (2022), the researchers examined the possible benefits of integrating art. Their findings showed that learning and teaching the fields included in STEAM education are ideally suited to enabling meeting and overcoming the challenges of the 21st century. Another study (Jantassova *et al*., 2022), which examined the effectiveness of STEAM education, showed that structural engineering students who were taught using a variety of STEAM programs reported higher innovativeness, greater ability to collaborate, broader vision in their studies and problem-solving abilities.

Following the implementation and evaluation of an innovative curriculum for teaching sound, waves, and communication systems, Awad and Barak (2018) wrote about the effect of the integration of lab and project experience in STEM learning on students' level of interest, achievements, and motivation, and on their attitudes toward science and technology. In addition, Reynders *et al*. (2020) reported about the need to assess critical thinking and information processing in the STEM course, with the aim of allowing instructors to focus on issues such as self-regulated teaching techniques, feedback, and procedural work capabilities toward improvement among students. Following these many characteristics of STEM education, it is realized that the teacher training process is very vital and significant. This support for STEM education is a critical factor for effective education through this education method (Garneli *et al*., 2015).

Research Questions

1. How are the interdisciplinary principles of STEM education expressed in a study unit developed by the teachers?
2. How do teachers studying for a graduate degree in science education perceive the integration of a 3D printer in STEM education?

Materials and Methods

The research comprised two sections. The first section related to the interdisciplinary principles of STEM education. The second section examined the integration of cutting-edge technology, using the example of a 3D printer, in STEM studies among teachers studying toward a graduate degree in science education.

In this study, a qualitative paradigm served as the primary research framework. Qualitative research paradigms stress the subjective experience, in order to expose and examine the unique context by developing a deep observational understanding of phenomena from the personal perspective of individuals participating in the research (Hamilton and Corbett-Whittier, 2012; Creswell *et al*., 2007; Patton, 2002). The focus of this type of study was to understand phenomena as they appear in the real world and through the eyes of those who experience them (Shakedi, 2012).

The first part of the research was conducted among 30 teachers from various knowledge areas. The teachers participated in a three-year continuing education program given in an elementary school and comprising 100 hours. The continuing education program was built in line with the needs defined by the school principal and the teachers' characteristics, according to the interdisciplinary educational essence of STEM subjects. The continuing education program comprised in-person and synchronous and a-synchronous online meetings. Table 1 outlines the three-year continuing education program.

[1]A branch of biology, chemistry, and physics that studies the way nature works in order to emulate it with a view to solving human problems.

Table 2. Types of problems, as perceived by the teachers (80 statements).

	Teachers' problems vis-à-vis themselves								Vis-à-vis students		
Problem type	**Management level**						**Content level**		**Actual experience**		**Total**
Statements	Arranging meeting times	Ramadan – Students' absence	Overcrowding in the classroom	Aligning with school timetable	Locating teaching aids (film, materials, a place to set up a compost	Interdisciplinary design and integrating	Exact interdisciplinary assessment	Choosing interdisciplinary subjects	Managing discourse among students, students 'difficulties in expressing themselves	The students focus on describing and have problems implementing the assignment	
in absolute numbers	14	8	5	5	4	15	10	4	4	11	80 statements
in percentage	18	10	6	6	5	19	12	5	5	14	100%

The research data were collected through analysis of questionnaires distributed to participants at the end of Stages 1 and 2 of the program which covered STEM characteristics, and via analysis of the summary integrative assignment developed by the teachers.

The teachers, who were examined in Stage 1 and 2, have not yet progressed to Stage 3. However, stage 3 was tested on 28 graduate degree students who were training to be elementary school teachers, with the aim of integrating the design and 3D printing processes into the three-year program for teachers. At the end of the experiential section, the attitudes of the students toward integration of advanced technology, represented by the 3D printer, in STEAM education were examined. They were required to note benefits and weaknesses in relation to the link between their experience with the printer and the rationale of STEM education, to note the added value of gaining experience with the 3D printer technology, and to note the degree of enjoyment from the experience.

Results

The first research question examines the teachers' attitudes toward various dimensions of STEM education in their classrooms, after they had taught the study unit they had developed. After demonstrating interdisciplinary subjects to the teachers, the teachers proposed relevant interdisciplinary topics according to principles such as integrating knowledge areas, suitability to the target audience and accessibility of materials.

The six study units that were developed by the teachers by the end of the continuing education program were intended for upper-level elementary school students – five Grade 6 classes and one Grade 4 classes. Only one unit was meant for Grades 1–2. The subjects of the developed study units were chosen by groups of teachers at the end of Stages 1 and 2 of the 100-hour program: commitment to protecting the planet, for Grades 1–2; missile launching and the application of thrust, for Grades 5–6; the feminine journey in space, integrated with the Koran and the Bible, for Grades 5–6; the Earth's rotation, the seasons of the year, and robotics, for Grade 5; building using plastic bottles, for Grades 4–5; sorting trash and building an underground school compost, for Grade 5; using open areas and transforming them into green spaces, for Grades 4–5. The study units were evaluated using an "indicator for assessing interdisciplinary learning products" (see Appendix 1) by three experts in science teaching and assessments. This indicator was developed in line with the goals of the interdisciplinary teaching aspects.

For the present research, the teachers were asked to describe their problems in teaching the interdisciplinary study unit, and to identify points to keep and points to improve. The teachers provided 80 statements that related to problems and the same number of statements focusing on points to keep. As to points to improve, the teachers provided 55 statements.

When the teachers spoke about the difficulties they faced when developing the interdisciplinary study unit and implementing it in the field (Table 2), they perceived themselves as primarily responsible for the problems arising in teaching it, both in terms of the level of class conduct and the level of the content being taught and the pedagogy surrounding it (about 81% of the statements). Less than half of the statements (about 36%) focused on

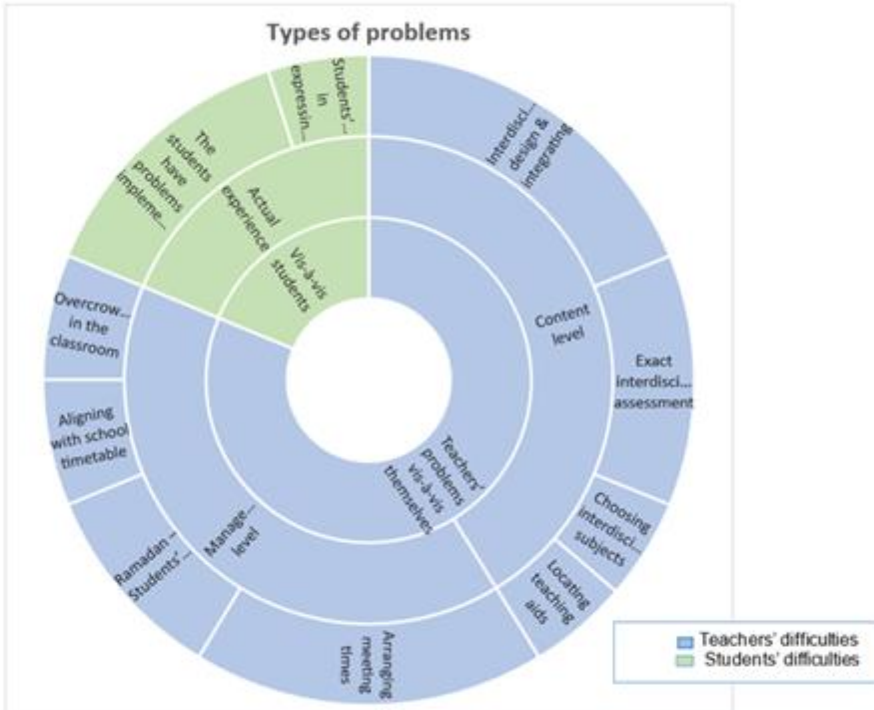

Figure 1. An illustration of the problems in relation to the teachers and the students.

Table 3. Positive points to retain, in teachers' opinions.

	Teachers relating to themselves					Teachers relating to students			Total
Statements	Team cooperation	Integration of thinking skills: Critical thinking, drawing conclusions, decision making, raising new ideas	Combing knowledge areas	Adapting learning materials and teaching methods to the student population	Development of an indicator	Work in groups/collaboration	Self-regulation, taking responsibility	Creating experiential learning and fostering motivation	
in absolute numbers	5	9	12	5	4	13	15	17	80
In percentages	5	11	15	6	5	16	19	22	100%

difficulties in planning and integrating the subjects of the interdisciplinary approach and in assimilating a valid and reliable assessment process. More than half of the statements (about 45%) focused on problems on the level of management such as arranging meeting times for teachers of different knowledge areas, the number of students in each class, aligning with the school's timetable and students' absences. Only around 18% reported problems related to students' functioning and dealing mainly with the ability to manage discourse and actually carry out the interdisciplinary assignment.

Figure 1 shows the relationship between difficulties arising from the teachers' functioning and the problems relating to students. The teachers are more critical when assessing themselves and identify many more positive points when discussing the students.

Table 3 presents the positive points that should be kept, as reported by the teachers. These positive points can be

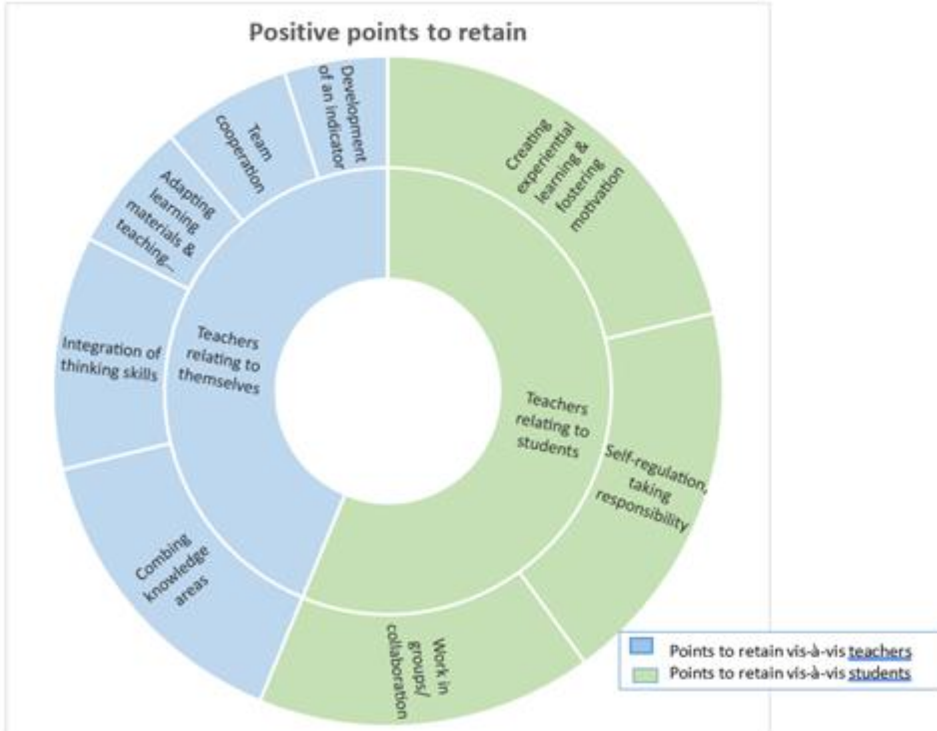

Figure 2. Positive points to retain vis-à-vis teachers and students.

Table 4. Points to improve, in the teachers' opinions.

	Vis-à-vis the teacher				Vis-à-vis the student			Total
Statements	Arranging a time for a meeting, learning to organize	Managing the class	Developing a structured interdisciplinary assignment	Assimilating the assessment approach	Managing students' dialogue	Behavior during class	Thinking at a high level	
In absolute numbers	7	11	7	15	4	9	2	55
In percentages	13	20	13	27	7	16	4	100%

divided into two types: points related to the teachers themselves (about 44% of the statements) and points related to the students made by the teachers (about 56% of the statements). Of the statements that teachers made about themselves, they noted that they want to keep the collaboration among different interdisciplinary teams, their ability to integrate thinking skills, and to match learning materials to the interdisciplinary assignments and the assessment tool development process to the interdisciplinary assignments.

Of the statements that relates to students' functioning, the teachers noted that they want to keep the collaboration among the teams, the experiential process whereby students learn by doing by building knowledge, and students' taking responsibility through self-regulation.

Figure 2 strengthens the picture presented by the findings and shown in Figure 1 – the teachers find more positive points to keep among students' behavior than among themselves.

In line with the findings presented in Tables 2 and 3, and as reflected in Table 4, the points needing improvement, as noted by the teachers, relate to themselves (about 73% of the statements) and a lesser number relating to the students (about 23% of the statements). Of the points to improve, related to the teachers, the main ones are the integration of the assessment approach and in descending order, the need to improve their ability to manage the class when teaching an interdisciplinary subject, in developing interdisciplinary assignments, and in arranging times for the interdisciplinary teams to prepare.

Of the points that should be improved among students, the teachers noted primarily the need to improve students' behavior in class when carrying out the interdisciplinary assignments (ability to listen, meet schedules, and take

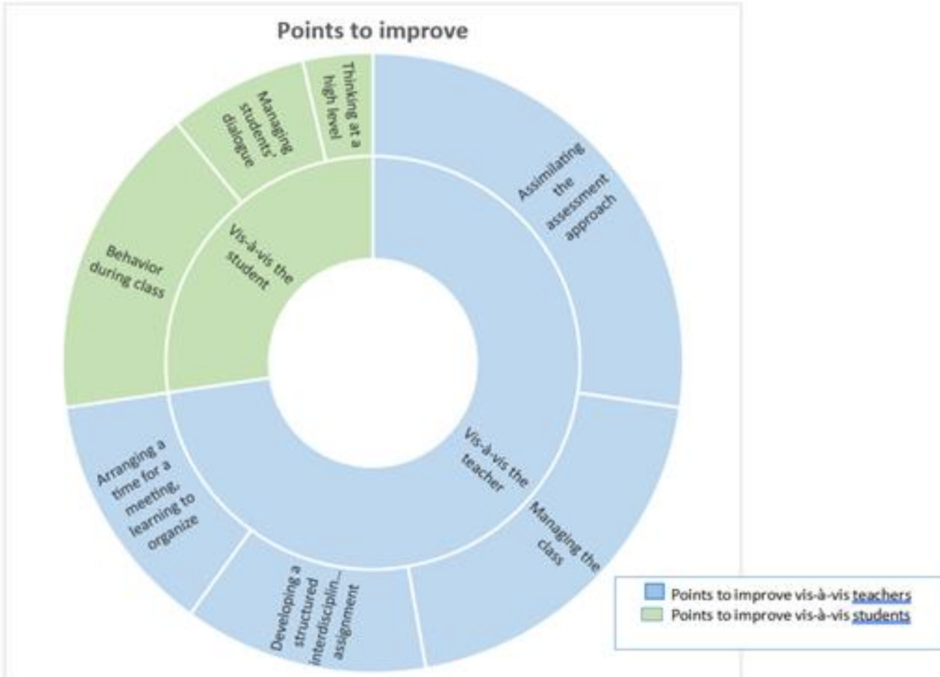

Figure 3. Points to improve vis-à-vis both teachers and students.

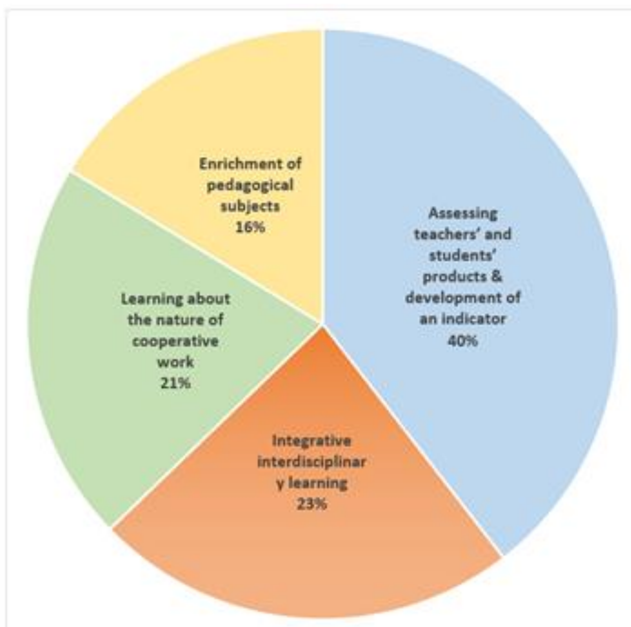

Figure 4: Distribution of statements about innovations identified by teachers in the STEM continuing education program (in percentages).

responsibility), the ability to engage in dialogue, and the ability to carry out assignments at a high thinking level.

The picture that arises from Figure 3 bolsters the impression given by Figure 1 – most of the points to improve relate to the teacher's management and functioning.

At the end of the program's Stage 2, 29 teachers were asked about innovations that they identified and learned about as part of the framework, both pedagogical and content-wise. Figure 4 presents their responses to these questions. The teachers provided 43 statements, which related to four main areas: evaluation of the teacher and

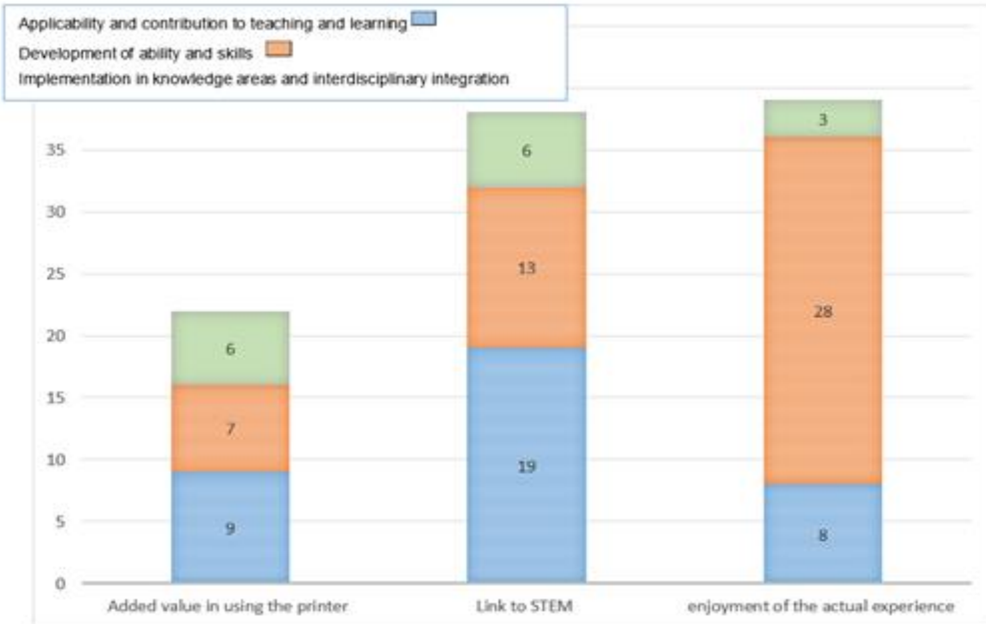

Figure 5. Distribution of the statements of the in-training students regarding integration of advanced technology through use of a 3D printer in STEM education (99 statements of 28 students)**.**

student products and indicator development – 17 statements; the essence of integrative interdisciplinary learning – 10 statements; learning about the nature of working (moderating and assessing) of collaborative teams – 9 statements; enrichment in pedagogical topics – 7 statements.

In the second research question, the students who were training to be teachers were asked to relate to the benefits and drawbacks of integrating advanced technology following their experience using the 3D printer in STEM teaching. Their responses provided 99 statements that related to benefits only: enjoyment of the actual experience (39 statements), to a connection with STEM (38 statements) and to the added value in its use (22 statements). The statements can be divided into three main themes: developing abilities and skills (50% of the statements), the importance of interdisciplinary integration (35% of the statements), and future applicability and demonstration (15% of the statements).

From Figure 5, the in-training students' enjoyment of the actual experience using the printer is seen. They mainly identify the development of students' abilities and skills (28 statements), the applicability of the printer's operation (8 statements) and focus less on the interdisciplinary integration (3 statements). The link to STEM is expressed primarily by the applicability of the 3D printer (19 statements) and in the development of students' abilities and skills (13 statements), and less by the interdisciplinary integration (6 statements). The added value in using the printer was the lowest level theme among the in-training students and was divided between applicability and contribution to the process (9 statements), development of abilities and skills (7 statements), and the importance of interdisciplinary integration (6 statements).

It appears that the in-training students not only experienced the process but also generated worthy products (Figure 6), which were designed and printed with the aim of being used as a teaching aid for the topics being taught.

1: A model comparing the planets in the solar system in terms of their size, location, and distance from the sun.
2-3: The characteristics of insects: wings, 6 legs, body parts - head, chest and stomach, a pair of eyes and antennae."
4: A model to demonstrate the relationship between surface area and volume.
5: A cross-section of lungs that enables demonstration of how their structure matches their function.
6: The echo chamber of a musical instrument, an ocarina, an ancient musical instrument, similar to a flute. It is round, with a hole on its side for blowing into, on its upper part; on its lower part, it has a number of holes for air to escape and create musical notes.

Following the presentation of products, a discussion was held regarding the limitations of the model in terms of its size, lack of mobility and that it was fixed to the base, its color, and the emergence of marks during its printing.

Discussion and Conclusions

Research has shown the need for increasing the number of students taking STEM subjects. This may be done,

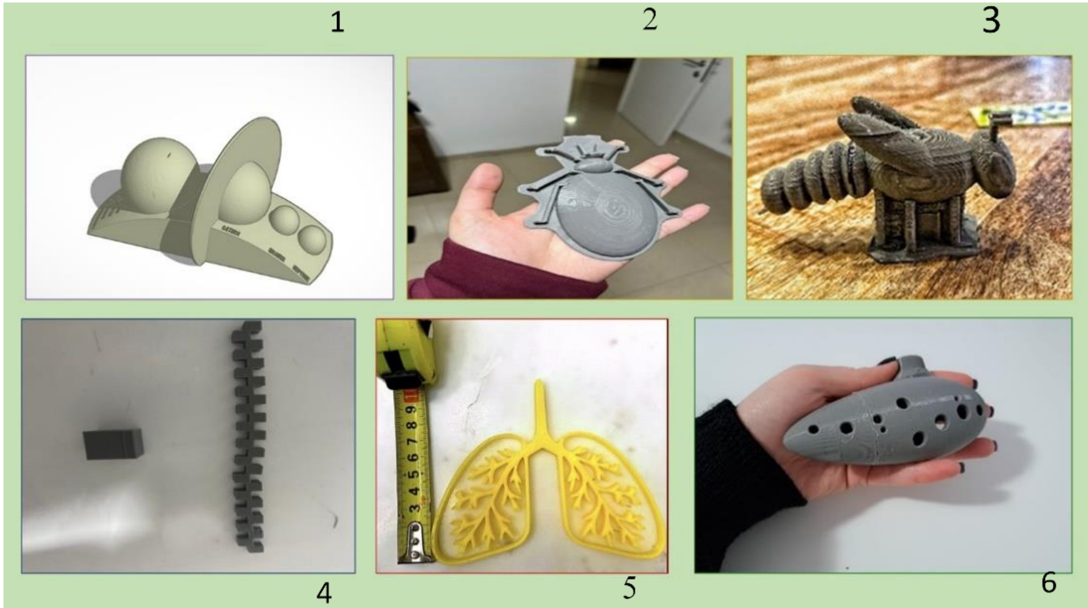

Figure 6. Teaching aids produced using the 3D printer.

among other ways, by increasing the number of students also among weak populations – an aspect that advances first and foremost equality in education. Among the recommendations, it is noted that advanced preparation for students before they choose further studies must be provided through appropriate courses. Likewise, support should be provided for teachers and the school organization, and interventions in early childhood education, both formal and informal settings, should be integrated.

Many studies have shown that a learning process according to STEM can improve cognitive skills (Weyer and Dell'Erba, 2022). Skills like reflective thinking, critical thinking, cross-checking, and combining data sources and information evaluation prepare students to cope with a complex world. This approach allows educators to teach while integrating problem-emerging skills to equip students (Xue, 2022).

Interdisciplinary learning is necessary for dealing with big questions that cut across knowledge areas. Division into knowledge areas is not a natural situation, and interdisciplinary education helps us better understand the world around us. The workforce requires professionals who can think deeply, be flexible and creative in their thinking, and take initiative. Graduates of the education system will be required to adapt themselves to the changing reality (Young *et al*., 2016).

A main challenge is to create integration between different ideas such that multidisciplinary learning is mostly turned into interdisciplinary learning. Sometimes, interdisciplinary learning is perceived as superficial, without depth. In our opinion, however, delving into disciplinary ideas that contribute to understanding an interdisciplinary subject is an essential condition for creating links between disciplines. In this way, interdisciplinary learning may develop new observations from assorted points of view about the interdisciplinary subject.

The continuing education program discussed here established a common basis for all the teachers and afterwards enabled them to experience a guided personal process that offered them opportunities to develop in line with their individual perspective. At the end of Stage 1 of the research, which as noted was conducted among teachers who participated in a continuing education program in an elementary school with face-to-face meetings and online synchronous and a-synchronous meetings, the teachers were asked to develop a study unit. This model of continuing education is reinforced by Bybee (2013), which emphasizes on integration, relevance, twenty-first-century learning skills, challenge the students, and mix it up by providing a variety of instructional tasks and ways for demonstrating their understanding.

The group of teachers chose seven subjects: (1) commitment to protecting the planet, (2) missile launching and the application of thrust, (3) the feminine journey in space, (4) integrated with the Koran and the Bible, (5) the Earth's rotation, (6) the seasons of the year, and (7) robotics, building using plastic bottles, sorting trash, and building an underground school compost, and using open areas and transforming them into green spaces. The teachers' products reflect the significant assimilation of the features of the teaching approaches to STEM education. In the study unit, expression is given to the natural connection between knowledge areas, and choosing topics relevant to students' world. A considerable number of teachers combined acquiring experience in the design planning process and 21st century skills and developed appropriate assessment tools. Most of the study units that were developed were intended for students in the higher levels of elementary school and highlight the cognitive challenge students faced with these units were required to handle.

When examining experiences with assimilating interdisciplinary learning, it can be seen that a strategy for fostering the pedagogy that accompanies the teaching in a STEM approach, in order to provide the mediating framework required for teaching that aligns with students' cognitive development and for the continuing interdisciplinary study programs, is essential. Despite the difficulties, it appears that the teachers are satisfied with the way they worked on the interdisciplinary subjects and the way their students' function. The teachers see the interdisciplinary learning as advancing central pedagogical goals. The way the teachers related to the question about innovation during the continuing education program also indicates their positive attitude toward the process they underwent.

The teachers were interested in overcoming the difficulties, especially those related to classroom management and organization and to the students' behavior. Samara and Kotsis (2023) reported about teachers' perceptions of applying this approach in schools. They were positive and noted that it promotes interest in learning fosters motivation and 21st century skills such as problem-solving, teamwork, critical thinking, creativity, and students' inquiry skills. There are areas in which the teachers had problems and that they noted these as points to improve. In other words, the difficulties do not frighten them, and the teachers were prepared to cope with them. For example, the teachers had problems in precise assessment of the product, yet exactly because of these problems they experienced, they recognize the need to improve everything related to the assessment approach.

From the evaluation perspective, the necessity and importance of support in establishing the STEM culture express economic and moral aspects (Quigley *et al*., 2019; Weld, 2017). Weld claimed that in order to assure success in implementing intelligently a culture such as this, a systems approach – and not a local or pointwise approach – is required. This approach includes all the educational dimensions: teacher training and professional development, appropriate timetables, parent–student relations, currficulum, assessment, appropriate learning space, integration of community and business sector and budgets. According to this report, STEM is perceived as key to intellectual development. Following the characteristics of STEM education as proposed by Garneli *et al.* (2015), it is suggested not to give up the teacher training process, which is very essential and significant. This support for STEM education is a critical factor for effective education.

A great challenge is to develop criteria for evaluating the interdisciplinary process and product. An adjusted indicator for evaluating an interdisciplinary outcome was developed based on Kidron, 2019 (see appendix 1). It was found that teachers have difficulties in assimilating an assessment approach in their classroom when teaching interdisciplinary subjects, even when an indicator for assessment of the interdisciplinary product has been prepared. From the findings, it is seen that there is a gap between the knowledge and practice essential for interdisciplinary integration during learning process and those related to assessing its results. It appears that practical tools for evaluating the interdisciplinary connection and the innovative interdisciplinary learning are lacking. Traditional tools for evaluating knowledge areas and skills from a single discipline are still being used today. There, the researchers of this study suggest a validated indicator, which has been field tested, for assessing interdisciplinary products (see Appendix 1).

The second part of the research examined the integration of modern technology, represented by a 3D printer, in STEM studies among in-training student teachers. The research showed that these students identified only benefits from the experience. They enjoyed the actual experience of using the printer and, identified the environment as developing students' abilities and skills. The link to STEM was expressed primarily in the application of operating the printer and developing abilities and skills.

In agreement with the approach of Reinking and Martin (2019), it was found that using the 3D printer in STEM classes can lead to a unique learning experience involving advanced technology that combines active participation by the student, heightens creativity and innovativeness, improves analytical skills, problem solving over the long term, and critical thinking. The experience can also foster students' imagination up to the point of actual application in reality and boost design thinking. These skills can help people cope with global problems later in life.

The study found that integrating a 3D printer in STEM studies, integrating with art, is very important. The connection is natural and contributes to students' using skills and acquiring tools that will help them fit in the 21st century technological society – alongside greatly enjoying themselves, feeling that they are realizing their potential in handling a problem having many solutions and coping with challenges. These findings are supported by Pramesti *et al*. (2022), about the benefits of integrating art. As stated before, their findings showed that learning and teaching the fields included in STEAM education are ideally suited to the challenges of the 21st century.

3D printers should be made part of high school curricula. Every school should have such a 3D printer and the necessary materials so that students are exposed to this field. The experience using a 3D printer in school ensures that students will be responsible for the results of the assignment that requires them to use their imagination while getting the opportunity to experiment with resources to reach results that may be successful or a failure. This experience can transform the process into something realistic and relevant to the digital space while also requiring involvement and the possibility of developing an educated, learning, and progressive community.

Recommendations for future research

The research (Stage 1) was conducted among elementary school teachers only. Identifying the perspectives of high school teachers vis-à-vis the STEM approach may broaden the understanding regarding teachers' views on teaching this approach.

REFERENCES

Awad N, and Barak M (2018). Pre-service Science Teachers Learn a Science, Technology, Engineering and Mathematics (STEM)-Oriented Program: The Case of Sound, Waves and Communication Systems. Eur. J. Math. Sci. Technol. Edu. 14(4):1431-1451.

Creswell JW, Hanson WE, Clark Plano VL, and Morales A (2007). Qualitative research designs: Selection and implementation. The Counseling Psychologist. 35(2):236-264.

Garneli V, Giannakos MN and Chorianopoulos K (2015). Computing education in K-12 schools: A review of the literature. IEEE Global Engineering Education Conference (EDUCON), Tallinn, Estonia.

Hamilton L, and Corbett-Whittier C (2012). Using Case Study in Education Research. Sage.

Helmane I, Briska I (2017). What is Developing Integrated or Interdisciplinary or Multidisciplinary or Transdisciplinary Education in School? Signum Temporis, 9(1):7-15. doi:10.1515/sigtem-2017-0010.

Jantassova D, Churchill D, Shebalina O, Akhmetova D (2022). Capacity building for engineering training and technology via STEAM education. Educ. Sci., 12(11):737. https://doi.org/10.3390/educsci1211 0737.

Kidron A (2019). Interdisciplinary learning activity in the education system. Literature review for the Office of the Chief Scientists and the pedagogical secretary. Ministry of Education. https://meyda.education .gov.il/files/LishcatMadaan/InterdisciplinaryLearningBooklet.pdf.

King D, English LD (2016). Engineering design in the primary school: applying stem concepts to build an optical instrument. Int. J. Sci. Edu. 38(18):2762-2794. http://dx.doi.org/10.1080/09500693.2016.1262567.

Patton MQ (2002). Qualitative Research and Evaluation Methods (3rd edition). Thousand Oaks, CA: Sage.

Pramesti ACA, Ridha AA, Oktaberliana DW, Harjunowibowo D (2022). Can STEAM-Based Learning Improve the Skills of 21st Century Student Post Pandemic? Specialusis Ugdymas, 1(43):8602-8614.

Quigley C, Herro D, Shekell C, Cian H, Jacques L (2019). Connected Learning in STEAM Classrooms: Opportunities for engaging youth in science and math classrooms. Int. J. Sci. Math. Edu., 18(8):1441–1463. https://doi.org/10.1007/s10763-019-10034-z.

Reinking A, Martin B (2019). Five ways to integrate STEM. New Teacher Advocate 26(3): 22-23.

Reynders G, Lantz J, Ruder SM, Stanford SM, Cole RS (2020). Rubrics to assess critical thinking and information processing in undergraduate STEM courses. Int. J. STEM Edu. 7(9):1-15. https://doi.org/10.1186/s40594-020-00208-5.

Samara V, Kotsis KT (2023). Primary school teachers' perceptions of using STEM in the classroom attitudes, obstacles, and suggestions: A literature review. Contemp. Math. Sci. Edu., 4(2):1-6, ep23018. https://doi.org/10.30935/conmaths/13298.

Shakedi A (2012). The meaning behind the words: methodologies in qualitative research - in practice: The Meaning behind the Words: Methodologies of Qualitative Research. Ramot Publishing - Tel Aviv University.

Vasquez JA, Comer M, Sneider C (2013). Integrating science, technology, engineering, and mathematics. Foreword by Rodger W Bybee. ISBN 978-0-325-04358-6 / 0-325-04358-2 / SKU E04358. 192pp / Paperback.

Young JC, Searle KR, Butler A, Simmons P, Watt AD, Jordan A (2016). The role of trust in the resolution of conservation conflicts. Biol. Conserv. 195:196-202.

Weld J (2017). Creating a STEM culture for teaching and learning. Arlington, Virginia: NSTA.

Weyer M, and Dell'Erba M (2022). Research and Policy Implications of STEAM Education for Young Students. Education Commission of the States. https://www.ecs.org/wp-content/uploads/Research-and-Policy-Implications-of-STEAM-Education-for-Young-Students.pdf.

Xue H (2022). A new integrated teaching mode for labor education course based on STEAM education. Int. J. Emerg. Technol. Learn., 17(2):128-142.